December 1979

RESEARCH NOTE RM-379

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Recovery Potential of Fire-Damaged Southwestern Ponderosa Pine

John H. Dieterich[1]

The survival potential of fire-damaged ponderosa pine is dependent on many factors, including season when the fire occurs, percentage of crown scorch, and consumption of live crown material. Other factors influencing survival include site conditions, available growing season moisture, and incidence of insect attacks.

Keywords: Fire damage, fire effects.

Management Implications

Ponderosa pine (*Pinus ponderosa* Laws.) damaged by dormant-season fires frequently show remarkable signs of recovery during the first growing season following the fire. The unnecessary removal of crop trees or potential crop trees could be prevented if a method were developed to allow those doing the salvage marking to distinguish between killed or badly damaged trees and trees having a good chance for survival.

Nearly all aspects of predicting fire damage in southwestern ponderosa pine need additional study before a final set of guidelines can be prepared. Nevertheless, some observations can be made that should help in predicting whether given trees should be removed in salvage cutting or remain as growing stock.

[1]*Principal Research Forester, Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Tempe, in cooperation with Arizona State University. Station's headquarters is at Fort Collins, in cooperation with Colorado State University.*

Figure 1.—Average scorch height of about 25 feet was measured on this clump of trees burned early on the morning of November 2. The clump is near sample area No. 1.

General

1. Season of fire occurrence and degree of crown scorch or consumption are of primary importance in predicting damage and mortality.
2. Extent of cambium damage is also important but is difficult to assess.
3. When residual growing stock is important, a two-stage marking system may have application. During the first entry, mark only those trees for removal that are obviously dead or dying; follow up with a second marking to remove trees that have subsequently died or that need to be removed because of form, spacing, etc.
4. Trees that survive past the second growing season have survived the most critical period.
5. Removal of a large percentage of live crown by scorching can result in reduced growth the first year. Growth should return to normal during the second and third growing seasons.

Dormant-Season Fires

1. To improve the tree selection process, delay marking fire-damaged trees until after growth has started in the spring.
2. If scorch height is 90% or more of live crown, mark for removal.
3. If crown consumption is observed on trees that are scorched more than 80%, mark for removal.

Growing-Season Fires

1. If salvage marking can be delayed until after the start of the next growing season without causing unacceptable decline in wood quality in dead trees, the damaged tree selection process will be improved.
2. If the above delay is feasible, mark according to instructions for dormant season fires.
3. If marking cannot be delayed, all trees with crown scorch greater than 70% should be removed. If crown consumption is observed, mark tree for removal regardless of percentage of crown scorch. (Conclusion based in part on information from other studies.)

Introduction

Marking fire-damaged trees for salvage following wildfire is at best an uncertain operation. Trees that have been burned so badly they are essentially dead after the fire front has passed are easily identified, and it is relatively simple to identify trees that have sustained little or no damage from fire. The marginal trees are difficult to identify—those trees that have sustained considerable damage but may yet survive.

Future development of the stand and its ability to recover and produce acceptable amounts of wood fiber depend on the ability of the timber marker to select which trees to cut and which to leave. There are few guidelines available to help the timber marker decide which trees to cut and which to leave as he inspects for visible fire damage (Herman 1954, Lynch 1959, Wagener 1961). Prematurely removing sapling and pole-size trees that have been damaged but not killed has the dual effect of removing potential crop trees and eliminating an important seed source needed to regenerate the stand naturally.

The study described here and a study by Rietveld (1976) were prompted by the observation that many fire-damaged trees were showing remarkable signs of recovery during the first growing season following a November wildfire. Severely scorched trees were putting on new growth, and cones that had developed the previous year were continuing to develop to maturity. The objective of this study was to supplement existing knowledge concerning survival of fire-damaged ponderosa pine, with an ultimate goal of eventually developing guidelines for more accurate marking of timber salvage operations. In addition, this note reviews some of the factors that are important in gaining a better understanding of fire damage, and demonstrates how a description of fire characteristics can be used to more accurately interpret fire damage.

Literature

Rietveld (1976) studied cone and seed development on the same study area described in this paper. He concluded that seedfall from foliage-scorched trees represented an important seed source for naturally regenerating the area and that, while cone size, seed soundness, and seed weight were markedly less in severely scorched trees, trees with crowns scorched as much as two-thirds produced viable seed. Nelson (1952) found that pine needles were killed almost instantly when exposed to temperatures of 147° F, whereas at 125.6° F they withstood 9-11 minutes of heat. Hare (1961) indicated that the lethal temperatures for some 20 species of plants varied from 113° to 139° F. This explains in part why damage occurs more readily when air temperatures are high—less heat is required to raise the ambient air to a lethal temperature. It also explains why scorch is minimized during cold weather. Byram (1958) recognizes air temperature and vegetation temperature as being important and uses the following example as an illustration of their relationship.

> "On a cold day when temperature is 4° C (39° F) a fire heats the needles of a pine to 102° C (216° F). The crown would thus be completely scorched. However, the buds with their higher heat capacity might be heated to only 38° C (100° F) and would remain undamaged. On a hot day when the initial vegetation temperature is 32° C (90° F) the needles of a similar tree could be heated to the same temperature 102° C (216° F) by a somewhat lower intensity fire. In this case the buds might reach a temperature of 64° C (147° F) because of their initial high temperature. Hence, two different fires, one of which was relatively cool on a hot day and the other relatively hot on a cool day may result in equal amounts of crown scorch. But the former may do considerably more damage to the trees than the latter because it should produce greater injury to the heavier parts of the tree such as the buds and cambium tissue. Thus crown scorch is not always a reliable indication of total damage."

Herman's studies (1950, 1954) of fire-damaged ponderosa pine resulted in the preparation of a simple guideline for marking trees for salvage following a growing-season fire (the Fort Valley Fire of July 1948). In preparing the marking guide, Herman identified two factors as particularly significant: (1) length of live crown killed by fire, expressed as percent of total crown length, and (2) fire intensity (not quantified) in the vicinity of the tree. He recommended two rules of thumb based on 6 years of observation and measurement: (1) removal of all trees with more than 60% of the length of live crown killed by fire; and (2) marking for removal all trees with 51-60% of

length of live crown killed if the fire in the vicinity of the tree was a heavy ground fire or a combination ground and crown fire. Herman suggested special attention should be given to trees of poor vigor because even relatively slight damage to these trees may be sufficient to cause their death.

Dormant-season fire studies by Wagener (1955, 1961) indicate bud kill, which is related to the season in which the fire occurs, is much more important than foliage kill in determining survival chances. He reported on physical changes that help in evaluating damage: twigs on which the needles are still present but show a "set" in an abnormal position—usually bent in the direction of the run of the fire—are also certain to be dead. On the other hand, if when using field glasses it is possible to see green bases on a portion of the needles, those twigs and branches, and possibly those nearby in other trees, are likely to be alive, regardless of whether or not all show green needle bases. Distinguishing between live and dead twigs becomes much easier after a few months have elapsed because dead needles are shed from the live twigs and branches, whereas the needles are retained for a longer period of time on the dead twigs and branches. The reason for these differences is that on living twigs and branches abcission layers continue to form releasing the dead needles; on dead twigs and branches growth stops and there is no new formation of the abcission layer. Wagener continues with the observation that, "... if no needles have been burned off or only those on a few lower branches, and if the greater part of the foliage on the trees hangs in a natural position, the percentage of live buds and twigs is likely to be high even though not much green foliage is evident." He recognized season, tree age, site, and extent of bud damage as being most important and noted there is a general tendency to overestimate mortality in cruising or marking a burn after a fire.

Lynch (1959) reported on a study of tree mortality from a July (growing season) wildfire in young ponderosa pine on the Colville Indian Reservation, Washington. He concluded that mortality was directly related to the percent of crowns "burned" and that virtually all the mortality occurred during the first 2 years following the fire. He found that small trees suffered greater mortality than large trees having the same degree of burn; that trees in the 6- to 9-inch d.b.h. class having more than 50% crown injury suffered temporary reduced diameter growth; and that height growth of the surviving trees was not affected by burning.

The effects of an early growing season wildfire on growth and survival of young ponderosa pine were studied by Pearson et al. (1972) on an area where a thinning study was in progress. The fire essentially destroyed an unthinned stand (basal area 126 square feet per acre) while an adjacent stand thinned to 20 square feet per acre was relatively undamaged. Following the fire, Pearson et al. selected 30 trees with crown damage in the range of 0-100% and, using increment borings, measured growth rates during three periods: (1) prior to thinning; (2) after thinning; and (3) after the fire. Radial growth increased on burned trees where crown scorch was less than 60% and, at least temporarily, decreased where crown scorch was more than 60%. Some growth was recorded on trees with percent of crown scorch up to 95% but it was below even the pre-thinning growth rate.

Fire Description

The Burnt Fire provided an opportunity to study the effects of a dormant-season fire on tree survival and growth in ponderosa pine. The fire started on the Mt. Eldon District of the Coconino National Forest, Arizona, and burned 7,150 acres between November 1 and 4, 1973.

A more complete description of the fire in terms of burning conditions, fuels, and fire intensity is needed to better understand the effects the fire had on the stand.

Weather

Weather on the fire was characterized by unusually strong winds (60 miles per hour) and temperatures ranging from about 25° F during the night to 55° F during the day.

Relative humidity was lower than normal during the week prior to the November 1 fire start, but minimum relative humidities recorded during the fire were not unusually low—in the 25-35% range.

The fire area was essentially without precipitation during September and October, only 0.03 inch being recorded. Only 1.25 inches of rainfall had fallen in August. Normal for these 3 months totals 7.13 inches making a deficiency of nearly 6 inches of rainfall. This moisture deficiency was reflected in the degree to which large fuels were consumed by the fire.

Rainfall records for the 4 years following the fire indicate a slight rainfall deficiency during the growing season for 1974 and 1975; near normal conditions in 1976; and above normal during the 1977 season. Total rainfall for the year was slightly below normal in 1974 and an equally small amount above normal during 1975 and 1976. Growing-season precipitation was well above normal in 1977. These records indicate rainfall amounts during the four growing seasons following the fire should have been adequate to provide a satisfactory environment in terms of available moisture for tree recovery and growth.

Fuels

Much of the area had been logged—some of it during the past 10 years. Some thinning had also been done in the area. Fuel treatment following these activities would be considered adequate in terms of present standards. Onsite fuel inventories were not available prior to the fire, but a reasonable estimate of fuel loading, based on measurements in similar stands following fuel treatment might be as follows:

Fine Fuels: litter, twigs, branches less than 3 inches diameter, grass and herbaceous material; 5 tons per acre.

Large Fuels: Branches and woody material greater than 3 inches diameter; 7 tons per acre.

Of this 12 tons per acre total, approximately 2-2.5 tons per acre of the lighter material was consumed in the moving fire front. Residual burning probably consumed an additional 5-6 tons per acre.

Fire Behavior

Intensity.—Rates of spread were difficult to reconstruct, but onsite observations indicated that for short periods of time, within major runs, the fire spread at rates approaching 1.25 miles per hour. Average rates of spread, however, were more in the neighborhood of one-fourth to one-half mile per hour.

Table 1 summarizes an assumed set of fuel, weather, and fire behavior parameters for November 2 on the Burnt Fire. Using these parameters, three additional values have been computed that characterize fire intensity—all of them useful in predicting and interpreting fire effects.

Figure 2.—Tree No. 578 experienced 80% crown scorch and some crown consumption was observed on the lower branches. In the 1977 photo the tree shows a 60% reduction in length of live crown with 12 feet of live crown remaining.

1974 1975

1976 1977

Figure 3.—Tree No. 579 was scorched on 95% of the crown. Length of live crown was reduced by 53% leaving approximately 14 feet of live crown when the 1977 photo was taken. Evidence would indicate that this tree should have been marked for removal, but it has since recovered, and growth is normal.

Table 1.—Synopsis—Weather, fuel and fire characteristics, Burnt Fire, November 2, 1973

	Daytime conditions		Night conditions
Estimated or measured	*High*	*Extreme*	
Air temperature	50° F	50° F	35° F
Wind velocity (20-ft standard)	30 mi/h	40 mi/h	20 mi/h
Available fuel[1]	2.5 tons/acre	2.5 tons/acre	2.0 tons/acre
Rate of spread	40 chains/h 0.73 ft/sec	90 chains/h 1.65 ft/sec	20 chains/h 0.366 ft/sec
Computed			
Byram's fireline intensity	672 Btu/ft/sec	1518 Btu/ft/sec	270 Btu/ft/sec
Flame length	9 ft	13 ft	6 ft
Scorch height	8 ft	14 ft	5 ft

[1]The amount of fuel consumed in the fire front.

Byram's Fireline Intensity is a quantification of the heat released per unit of length of fire edge, per unit of time. As points of reference, most prescribed fires should be below 100 Btu/ft/sec; wildfires that exceed 500 Btu/ft/sec are reaching fire intensities that preclude direct attack, and above 1,000 Btu/ft/sec major runs are likely. Flame length is directly related to fireline intensity and can be used to help predict height of crown scorch, which in turn can be used to assess the impact of the fire on individual trees and stand development. These fire intensity measures, or indicators, are further described by Albini (1976). Formulas for computing each of them are included.

Damage.—Damage from this fast-spreading fire was extremely variable ranging from complete destruction of crown material in patches of saplings and pole timber and an occasional mature tree, to large areas where the only evidence of fire was a blackened litter layer and slight scorch on the lowest portions of the crowns. Much of the stand was open-grown, and tree crowns extended to within 4-5 feet of the ground.

Strong winds and cool temperatures were responsible for average scorch heights below what might be expected with warmer air temperatures and lower wind velocities. For example, the group of trees in figure 2 has an average scorch height of about 25 feet. The computed scorch height (table 1, extreme daytime conditions) is considerably lower than the observed. This difference emphasizes the need for additional validation studies, and for getting accurate on-site wind measurements. If the wind velocity were reduced from 40 to 30 miles per hour and all other conditions remained the same, scorch height would have been computed to be 21 feet—reasonably close to the observed 25 feet.

Methods

A tree damage assessment study was undertaken starting in September 1974, 10 months after the fire. Twenty-five trees were selected at two locations approximately 1 mile apart. Both sites were burned over in the early stages of the fire, and the trees appeared to have been exposed to fires of roughly the same intensities. The trees selected showed at least 75% crown scorch; some showed partial crown consumption, and all were within the d.b.h. range of 6-14 inches. No attempt was made to assess the extent of cambium damage during the first inspection in 1974. Notes were made on fire scars as they became evident during subsequent visits to the site. Percent of crown scorch was determined, and the trees were photographed from a photo point, so that subsequent photos could be used to show changes in the general condition of the tree. The trees were rephotographed in September 1975, 1976, and 1977, and observations were recorded concerning the general condition of the tree, persistence of dead needles, presence of insects, cone development, and, of course, if the tree had died.

Results and Conclusions

The factors that influence the ability of the individual trees to survive the effects of fire, include (1) percent of crown scorch and/or crown consumption, (2) extent of cambium damage, (3) season in which the fire occurs—which in turn influences plant physiology, (4) presence of insects, and (5) rainfall during the growing seasons following the fire.

Figures 2, 3, and 4 illustrate graphically the changes that occurred in crown development on three sample trees following this November wildfire. The photographs were taken at 1-year intervals starting in September 1974, 10 months after the fire.

Results of these observations indicate the following:

Of the 25 trees tagged for observation, 6 trees (24%) were dead at the end of the fourth growing season. Two of these died between the 1974 and 1975 observations; three died between the 1975 and 1976 observations; and one additional tree died between the 1976 and 1977 observations.

Fire scars were detected on two of the trees during the 1975 observation. No other cambium damage was apparent during subsequent visits to the sites.

Some crown consumption was noted on 7 of the 25 trees. Of the six trees that were dead after the 1977 growing season, some crown consumption had been noted on four of them. Three trees that experienced crown consumption have since survived, apparently because they suffered no more than 90% crown scorch. Tree No. 578 (fig. 2) was one of the seven trees on which crown consumption was observed. It had 80% crown scorch and has since recovered completely.

By the end of the second growing season (1976) there was a 50-70% reduction in length of live crown. By the end of the 1977 growing season, bases of live crowns were averaging 16 feet above ground level and crowns were

continuing to develop normally. Prefire crown base levels averaged 5-6 feet above ground.

Needle persistence was variable but most dead needles had fallen by the second observation, 23 months following the fire. Probably more than 80% of the needles dropped off during the second winter following the fire.

In September 1977, three growing seasons after the fire, increment cores were taken from each of the living sample trees. Two-thirds of the trees had a slightly suppressed growth ring the first year following the fire but by the second and third years were growing at or above the prefire growth rate; two of the trees showed a reduced growth rate for the three seasons. The remaining trees showed growth rates that were normal or above normal for the three growing seasons.

Literature Cited

Albini, Frank A. 1976. Estimating wildfire behavior and effects. USDA For. Serv. Gen. Tech. Rep. INT-30, 92 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Byram, George M. 1958. Some basic thermal processes controlling the effects of fire on living vegetation. U.S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn., Res. Note 114, 2 p. Asheville, N.C.

Hare, Robert C. 1961. Heat effects on living plants. U.S. Dep. Agric., South. For. Exp. Stn., Occas. Pap. 183, 32 p. New Orleans, La.

Herman, F. R. 1950. Survival of fire-damaged ponderosa pine: A progress report. U.S. Dep. Agric., For. Serv., Southwest. For. and Range Exp. Stn., Res. Note 119, 3 p. Tucson, Ariz.

Herman, F. R. 1954. A guide for marking fire-damaged ponderosa pine in the Southwest. U.S. Dep. Agric., For. Serv., Rocky Mt. For. and Range Exp. Stn., Res. Note 13, 4 p. Fort Collins, Colo.

Lynch, Donald W. 1959. Effects of a wildfire on mortality and growth of young ponderosa pine trees. U.S. Dep. Agric., For. Serv., Intermt. For. and Range Exp. Stn., Res. Note 66, 8 p. Ogden, Utah.

Nelson, Ralph M. 1952. Observations on heat tolerance of southern pine needles. U.S. Dep. Agric., For. Serv., Southeast. For. Exp. Stn., Stn. Pap. 14, 6 p. Asheville, N.C.

Pearson, H. A., J. R. Davis, and G. H. Schubert. 1972. Effects of wildfire on timber and forage production in Arizona. J. Range Manage. 25(4):250-253.

Rietveld, W. J. 1976. Cone maturation in ponderosa pine foliage scorched by wildfire. USDA For. Serv. Res. Note RM-317, 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Wagener, Willis W. 1955. Preliminary guidelines for estimating the survival of fire-damaged trees. U.S. Dep. Agric., For. Serv., Calif. For. and Range Exp. Stn., Res. Note 98, 9 p. Berkeley, Calif.

Wagener, Willis W. 1961. Guidelines for estimating the survival of fire-damaged trees in California. U.S. Dep. Agric., For. Serv., Calif. For. and Range Exp. Stn., Misc. Pap. 60, 11 p. Berkeley, Calif.

1974

1975

976

1977

Figure 4.—The left side of the crown of tree No. 594 was scorched nearly to the tip by convective heat. Although the crown has lost some if its symmetry, it still contains more than 18 feet of live crown material. Note recovery of the two smaller trees in left side of the photo.